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Research Article

Noise Detection in Images using Moments

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Abstract: Noise is an unwanted signal that disturbs brightness/color information of an image. Image denoising algorithms often are directed by human intervention or assume the type of noise, such approaches are not fully automatic in detecting the presence of noise and also in identifying the type of noise. This study aims to introduce a moment based noise detection and identification technique to detect the presence of noise in an image and if so, whether the noise is impulse. The proposed method uses Discrete Cosine Transform to obtain frequency components over which the Kurtosis is calculated. The perturbation of kurtosis is computed in terms of Sum of Absolute Deviation (SAD). Based on the larger experimentation a threshold value is set to detect the presence of noise and based on the ranges of SAD value, types of noise is identified.

Keywords: Discrete cosine transforms, impulse noise, kurtosis, sum of absolute deviation

INTRODUCTION

Noise free images are intended for good interpretation of the data present in it. But noise gets added due to many factors including thermal effects, acquisition condition, sensor attenuation, A to D conversion and quantization (Gonzalez and Woods, 2009). These noises in the images are unwanted information that disturbs the data present in it and has to be eliminated irrespective of the source of noise. It should be filtered for not only enhancing the quality of image but also for further processing or analysis of the image such as edge detection, image segmentation, object recognition etc. Detection and identification of the noise is crucial for an image denoising model to be accurate. In the literature, there are several techniques available to detect the presence of noise and also to identify the nature of the noise (Suryanarayana *et al*., 2012; Santhanam and Radhika, 2010). Few researchers have worked on automatic noise identification (Bretto and Cherifi, 1997; Beaurepaire *et al*., 1997) based on statistical parameters (Benediktsson *et al*., 1990). Impulse noise detection was proposed by Panda *et al*. (2002) using ANN with in a local neighborhood of the test pixel. Once the image is classified as noisy, Discrete Wavelet Transform is applied to remove the noise. For distinguishing signal in non-Gaussian environment the usage of Kurtosis parameter was used by Tesei and Regazzoni (1995). A filter for estimation and removal of Gaussian noise was proposed by Russo (2003) using the Absolute Difference (AD) between test pixel and its eight neighborhood. Whether an image is corrupted or not, is determined by comparison of ADs with a varying threshold (p). The same algorithm is repeated for each p value in the range of (2 to L/4) where L is maximum value of the dynamic range of the test image. For each iteration, MSE is calculated and finally the image with minimum MSE is given as filtered output image. Shamik *et al*. (2011) suggested a method to classify the image noise using Neural Network. In this approach a multilayer neural network is used for the classification of image noise, the parameters used are mean, variance and 3^{rd}, 4^{th} and 5^{th} higher order statstics of the image. In this study a simple, Discrete Cosine Transform (DCT) and moments based method is presented to detect and identify whether the image is corrupted by impulse noise or not.

MATERIALS AND METHODS

Image noise is a random variation of brightness or color information of images produced by sensor circuitry of scanner or digital camera. It is an undesirable by product of image capture that adds spurious and extraneous information. Image function is given by f (i, j), where (i, j) is the spatial coordinate and ‘f’ is the pixel intensity at the point (i, j). Let f (i, j) be

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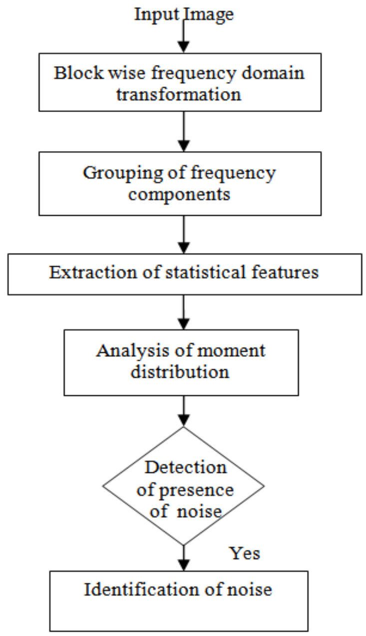


Fig. 1: Pipeline of the proposed methodology

the original image, g (i, j) be the noisy version, n (i, j) be the noise function which returns random values. Basically there are three types of noise models they are Gaussian noise, impulse noise and Speckle noise.

Impulse noise: Impulse (Salt and pepper) noise is sometimes called as 'spike noise'. Image containing this type of noise has dark pixels in brighter regions and bright pixels in darker regions. Salt and pepper noise is caused by dead pixels, A to D converter errors, bit errors in transmission, etc. Mathematical model for this noise is:

$$\begin{aligned} P(n_{pos}(i,j)=1) &= p \\ P(n_{pos}(i,j)=0) &= 1-p \end{aligned} \tag{1}$$

Impulse noise satisfies a binary distribution which indicates that at (i, j), the probability of having an additive impulse p and a probability 1-p that there is no noisy element in that pixel. The impulse noise takes on positive and negative values with an equal probability ½ p.

Process flow: The given input image may or may not be corrupted by noise. The noise gets added to an image during many situations as discussed earlier. Image denoising and enhancement is an important process in image processing for better interpretation of the data. Hence detecting the presence of noise prior to de-noising will reduce the effects of unnecessary filtering. The flow chart for the detection and of noise in images is shown in Fig. 1.

In this method, to identify the corrupted image, the image is divided into 8×8 blocks. DCT is applied to pixels in each block to move into frequency domain. The frequency components are grouped separately in the order of increasing frequencies and kurtosis is calculated for high frequency components. Based on the thresholding of SAD (SAD_{th}) the noise is detected if so, impulse noise can be identified when the SAD value falls into a particular range.

Frequency domain representation: The image is transformed from spatial domain into frequency domain by applying DCT on a block by block (8×8) basis as shown in Eq. (2):

$$B_{pq} = \alpha_p \alpha_q \sum_{i=1}^{M} \sum_{j=1}^{N} s(i,j) \cos\left(\frac{\pi(2i+1)p}{2M}\right) \cos\left(\frac{\pi(2j+1)q}{2N}\right) \tag{2}$$

$0 \le p \le M-1,\ 0 \le q \le N-1$

where,

$$\alpha_p = \begin{cases} \frac{1}{\sqrt{M}}, & p=0 \\ \sqrt{\frac{2}{M}}, & 1 \le p \le M-1 \end{cases} \tag{3}$$

$$\alpha_q = \begin{cases} \frac{1}{\sqrt{N}}, & q=0 \\ \sqrt{\frac{2}{N}}, & 1 \le q \le N-1 \end{cases} \tag{4}$$

where,
α_p, α_q = Normalization factors
s = Input image and M
N = Rows and columns of the image

Grouping of frequency components: The frequency components of DCT are arranged in the order of low frequency to high frequency components excluding the DC coefficient for each block as given in the Eq. (5). The corresponding frequency components of all blocks are grouped to form a vector of particular frequency:

$$\begin{aligned} &Block\ 1, \quad (f_1, f_2, \ldots f_H) \\ &Block\ 2, \quad (f_1, f_2, \ldots f_H) \\ &\quad \vdots \\ &Block\ n, \quad (f_1, f_2, \ldots f_H) \end{aligned} \tag{5}$$

Extraction of statistical features: The statistical features such as mean, standard deviation and moments are the most common to characterize a data set. Moments are calculated for high frequency component data sets and the distribution is plotted. Mean is the standardized first central moment of the probability distribution:

$$\mu = \frac{1}{M*N} \sum_{i=1}^{M} \sum_{j=1}^{N} S(i,j) \tag{6}$$

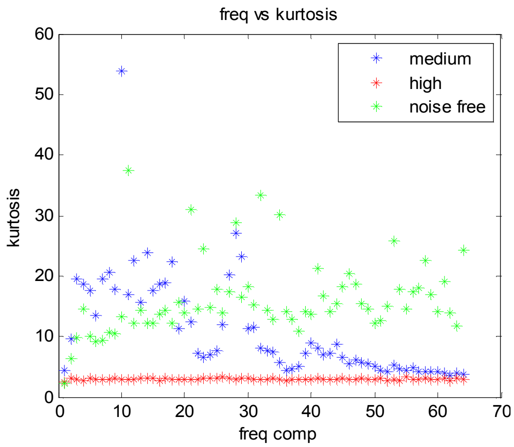


Fig. 2: Frequency components vs. kurtosis

where, S (i, j) is a pixel value.

Standard deviation indicates the amount of variation or dispersion existing from the average mean:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(S(i,j)-\mu)^2}{M*N}} \qquad (7)$$

Kurtosis is the standardized fourth central moment of probability distribution. It is a measure of peakedness of the distribution relative to Gaussian distribution:

$$K = \frac{1}{\sigma^4 (M*N)}\sum_{i=1}^{N}\sum_{j=1}^{M}(S(i,j)-\mu)^4 \qquad (8)$$

Kurtosis can be calculated for each frequency component datasets and plotted as shown in Fig. 2.

Analysis of feature distribution: The kurtosis of the frequency domain transformed noiseless image tends to be large enough and has more perturbations in its values, whereas the kurtosis of the frequency domain transformed noisy image comparatively decreases and the perturbation also drops down at high frequencies as shown in the Fig. 2. Thus the following two inferences can be made:

- Kurtosis value drops as the noise density rises irrespective of the type of noise.
- The distortion in Kurtosis value decreases with increase in noise densities at high frequencies irrespective of the type of noise.

Thresholding: A well-known fact is that the noise is likely to be present at higher frequencies. Hence taking into consideration the high frequency components and corresponding kurtosis values, the threshold is fixed based on the number of perturbations in terms of SAD value. SAD is calculated using the following equation:

$$SAD = \sum_{i=40}^{63} | K_i - K_m | \qquad (9)$$

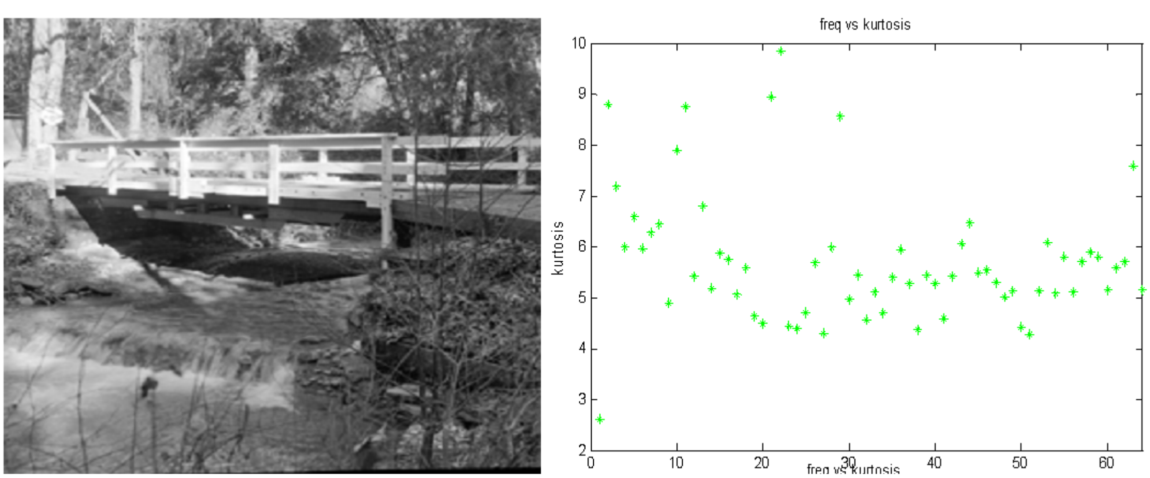
where, K_i is the kurtosis value of i^{th} higher frequency component and K_m is the mean of kurtosis values. SAD_{th} is chosen by experimentation. If the SAD of the input image is greater than the SAD_{th} the image is said to be a noise free image else noisy image. If the image is noisy, impulse noise is identified based on the range of SAD values.

RESULTS AND DISCUSSION

The proposed methodology is tested on 170 images using various low, medium, high information images from USC-SIPI Image Database.

The kurtosis values of a few noise free images of USC-SIPI Image Database are shown in Fig. 3 and 4.

Figure 5 and 6 illustrate the output of the house image and Lena image. The first row shows the original noise free image and its kurtosis plot, second and third



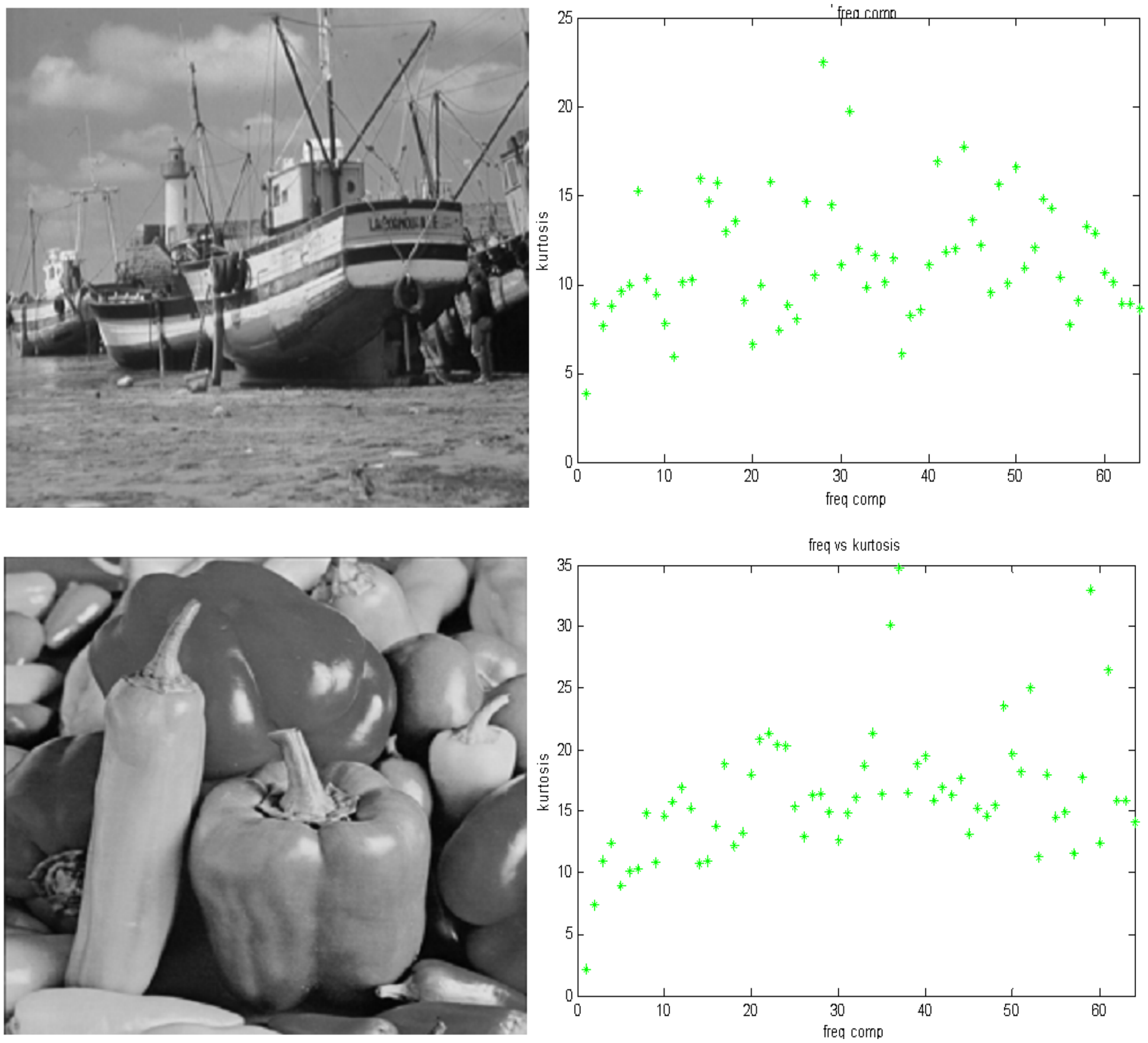


Fig. 3: Results of noise free images

rows contain images affected by low and high noise densities and the corresponding kurtosis plot. Figure 7, first row consists of original cameraman image with its kurtosis plot and rows 2, 3 consist of 1%, 50% impulse noise affected images and the corresponding kurtosis plots. From the empirical analysis, it is found that $SAD_{th} \geq 40$ for any noise free image and if an image is corrupted by impulse noise varying from 1 to 100% in steps of 1%, the SAD values of the images appear in the range of 2 to 40. Table 1 shows the SAD values calculated from images corrupted by impulse noise with levels 1 and 100%.

Though the proposed method has few wrong detections during testing, it is possible to attain accuracy close to 97%. The proposed frame work is validated with success rate (ξ) and wrong detection (φ) as shown in Eq. (10) and (11):

$$\xi = \frac{n}{\eta} \times 100\% \tag{10}$$

Table 1: Sad values of various images

Images	Sad value of low level noise (1%)	Sad value of high level noise (100%)
	36.2534	2.8009
	27.6434	2.2317
	28.6509	3.2992
	32.6391	3.3063
	29.9191	2.6885

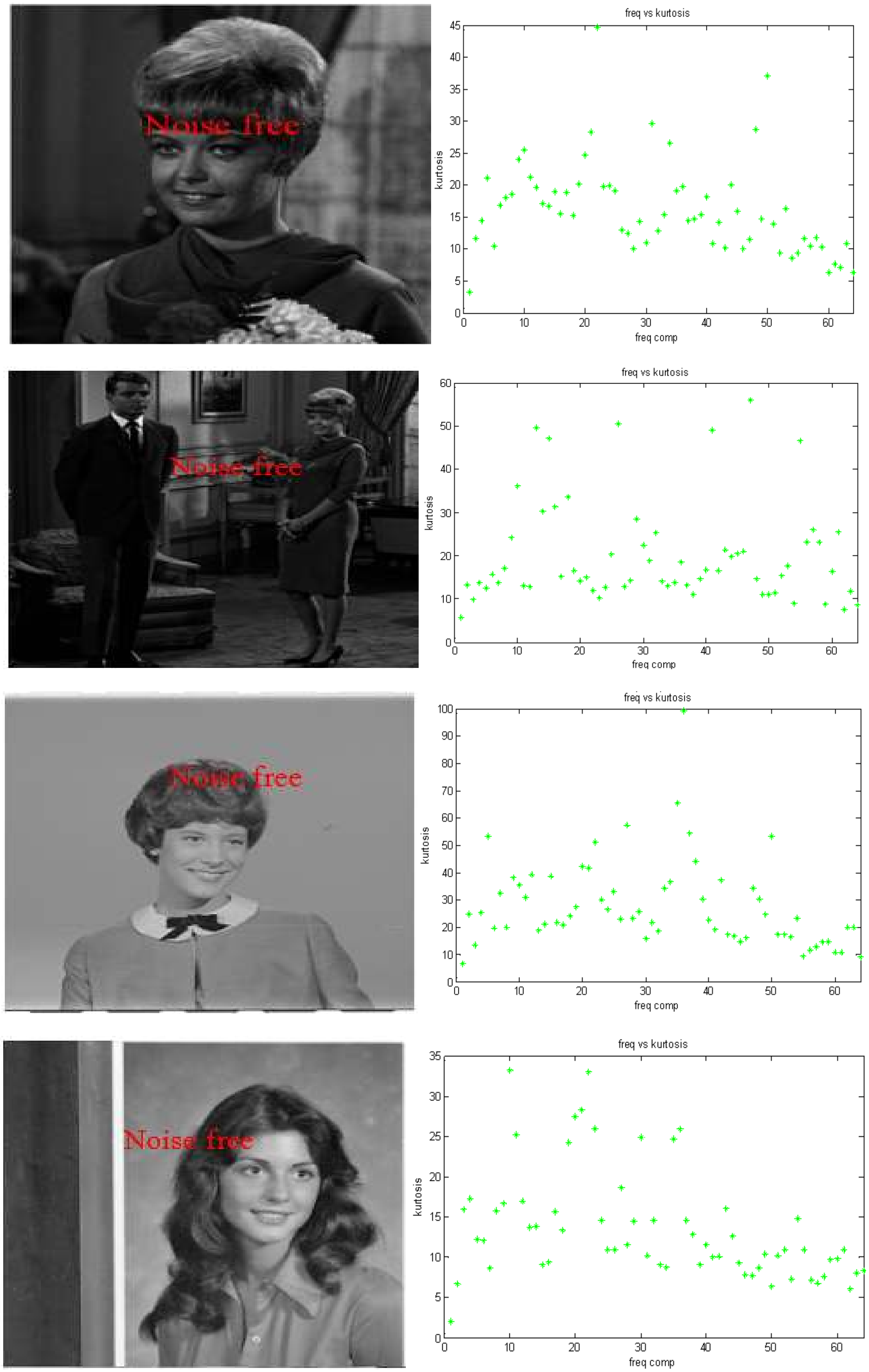


Fig. 4: Results of noise free images

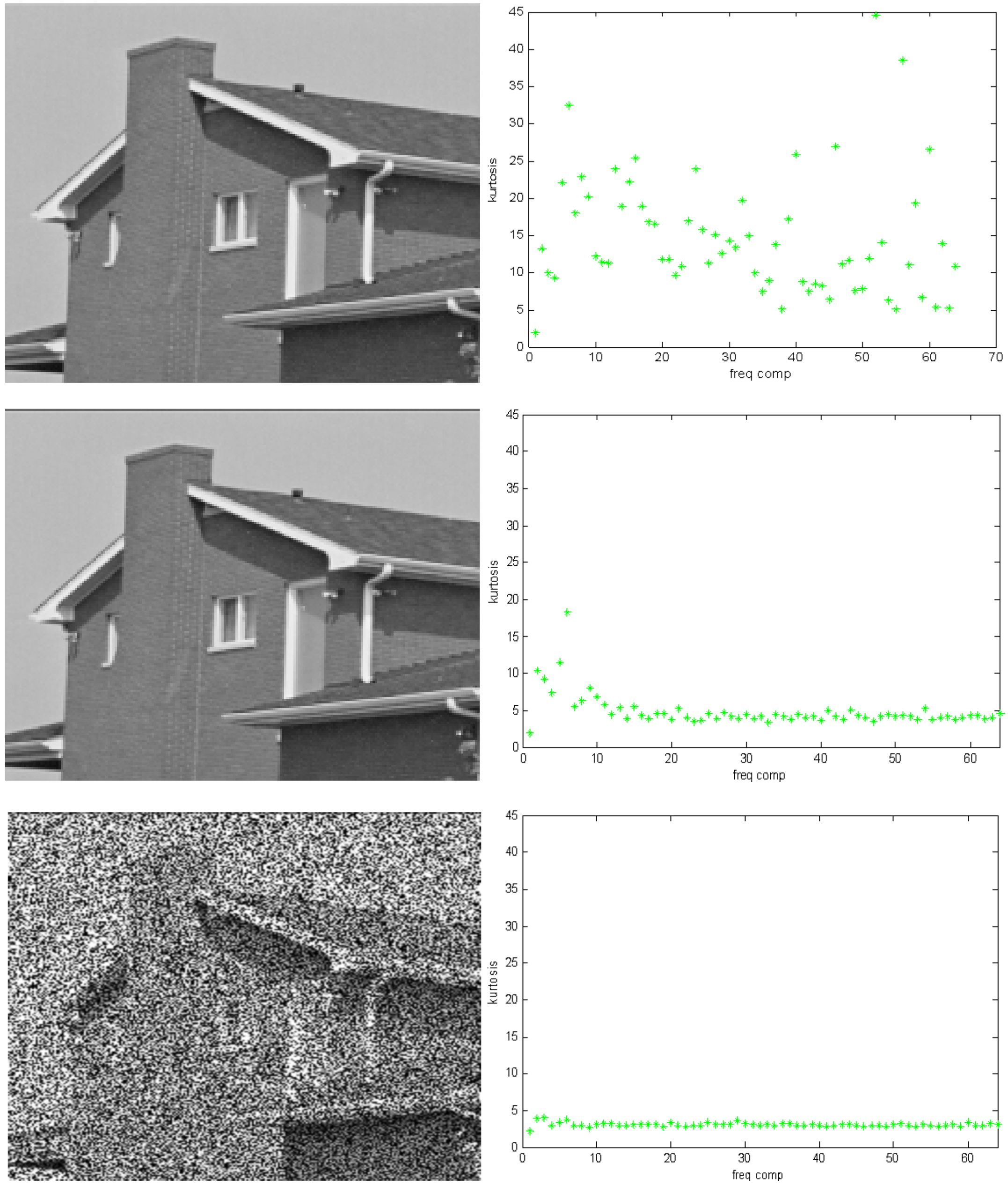
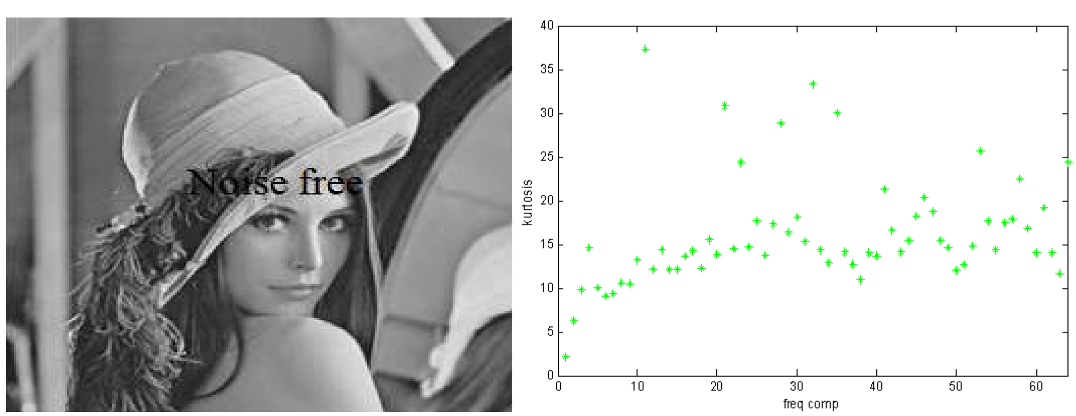


Fig. 5: Results of house image



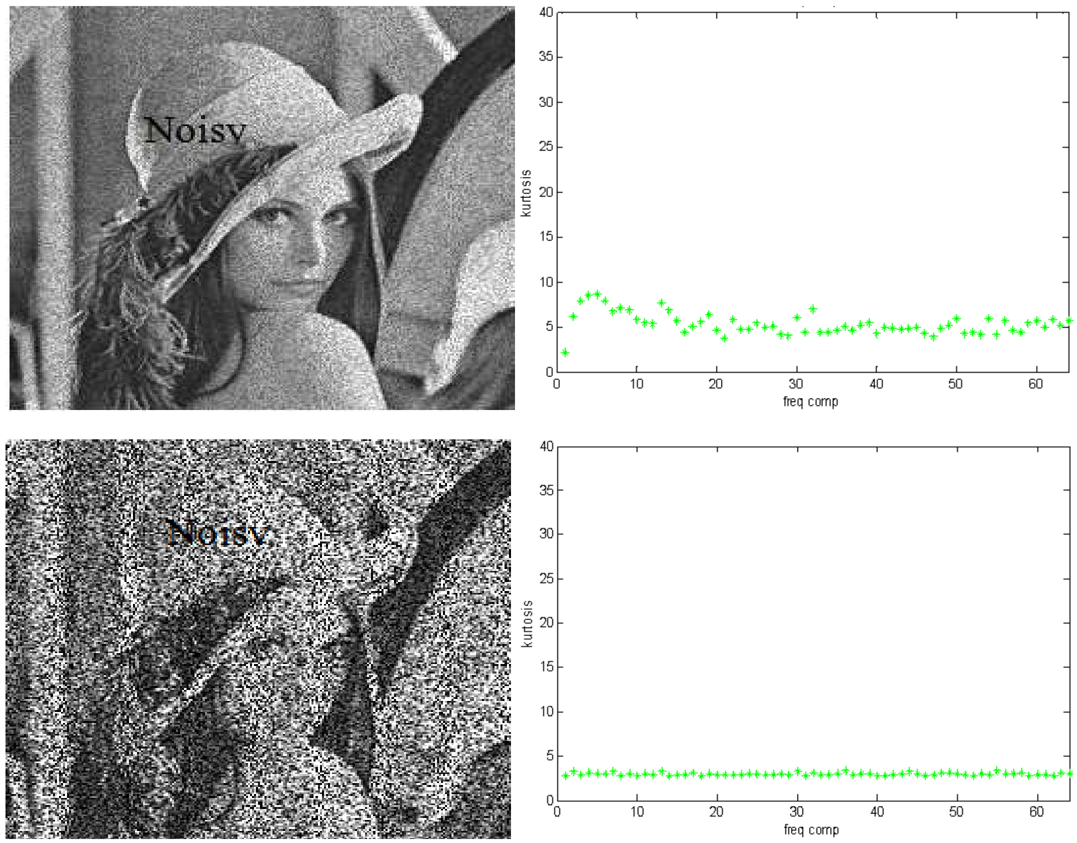
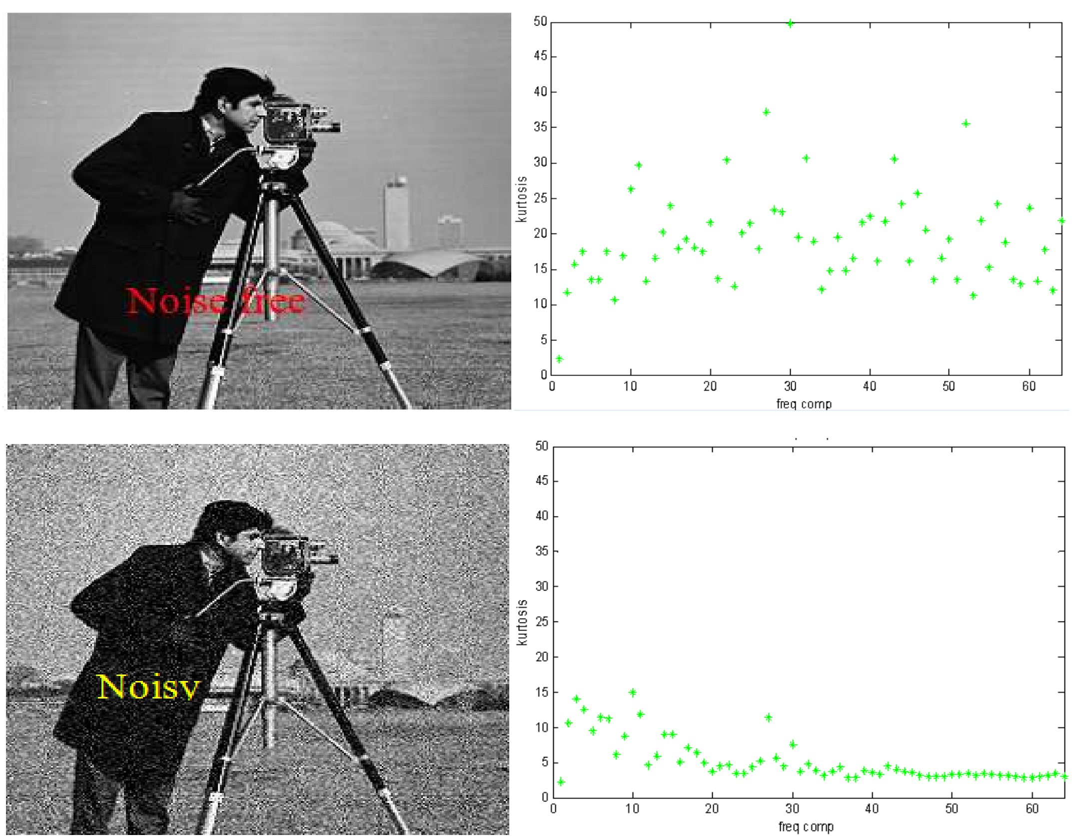


Fig. 6: Results of Lena images



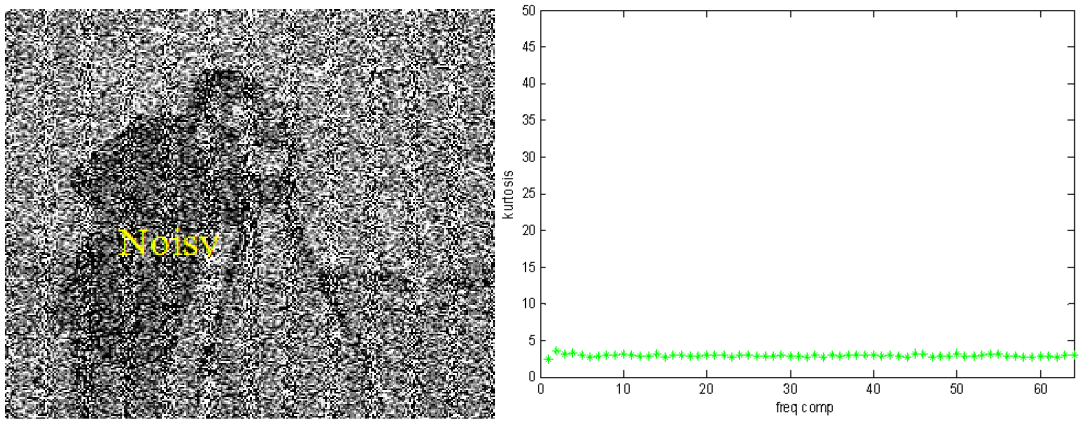


Fig. 7: Results of cameraman images

$$\varphi = 100 - \xi\ \% \tag{11}$$

where,
n = No of images correctly classified
η = Total of images tested

CONCLUSION

In this study, a simple statistical moment based method is developed for noise detection and identification of impulse noise. This technique uses DCT to provide frequency domain information of the image, where they are grouped by their bands. Statistical parameter-kurtosis is calculated and using the thresholded sum of absolute deviation the presence of noise and further presence of impulse is identified. Experimental results have been provided to substantiate the performance of the proposed method.

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